Running Head: Computer Simulation Study

A Prospective Computer Simulation Study to Test the Impact of Consolidating Primary Care Out-Patient Services at McDonald Army Community Hospital

A Graduate Management Project
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14. ABSTRACT
Computer simulation is an effective operational analysis tool gaining popularity in the healthcare field. Computer simulation is an objective, data driven decision support system that allows mangers to test solutions before implementation. A prospective computer simulation study was conducted at McDonald Army Community Hospital to aid in the possible consolidation of primary care operations. The primary goal of the study was to determine if the proposed floor plans could meet the access demands created by the consolidation of primary care operations and determine what is the most efficient combination of screening rooms, exam rooms and treatments rooms. Four models were developed using the MedModel computer simulation software. The models evaluated two possible floor plans and tested two processes of care that involved screening patients in separate screening rooms or in the exam rooms. A detailed analysis demonstrated that a combination of 5 screening rooms, 18 exam rooms, and 3 treatment rooms are sufficient to meet the demands of consolidated primary care operations and avoids a major construction project estimated near $300k. The analysis also demonstrated that the process of screening in exam rooms created a bottleneck and would require more than 20 exam rooms and additional staffing. The resources required to expand the floor plan beyond 20 exam rooms are financially prohibitive and not necessary. This study determined that the consolidation of primarycare operations is possible with minimal changes required to the current floor plan.

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Abstract

Computer simulation is an effective operational analysis tool gaining popularity in the healthcare field. Computer simulation is an objective, data driven decision support system that allows mangers to test solutions before implementation. A prospective computer simulation study was conducted at McDonald Army Community Hospital to aid in the possible consolidation of primary care operations. The primary goal of the study was to determine if the proposed floor plans could meet the access demands created by the consolidation of primary care operations and determine what is the most efficient combination of screening rooms, exam rooms and treatments rooms. Four models were developed using the MedModel computer simulation software. The models evaluated two possible floor plans and tested two processes of care that involved screening patients in separate screening rooms or in the exam rooms. A detailed analysis demonstrated that a combination of 5 screening rooms, 18 exam rooms, and 3 treatment rooms are sufficient to meet the demands of consolidated primary care operations and avoids a major construction project estimated near $300k. The analysis also demonstrated that the process of screening in exam rooms created a bottleneck and would require more than 20 exam rooms and additional staffing. The resources required to expand the floor plan beyond 20 exam rooms are financially prohibitive and not necessary. This study determined that the consolidation of primary care operations is possible with minimal changes required to the current floor plan.

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Introduction

Conditions Which Prompted the Study

McDonald Army Community Hospital (MACH), located at Fort Eustis, Virginia, serves 59,000 TRICARE beneficiaries (A. Armentrout, personal communication, November 9, 2000). MACH serves the community by providing outpatient/inpatient care, urgent care and a limited array of specialty services in a 36 year old, 30-bed health care facility.

In its inception, MACH's inpatient capacity was 116 beds. The addition of an outpatient wing in 1976 augmented the hospital's primary care capabilities and initiated a change of focus to outpatient care. In 1994, the Secretary of Defense approved the implementation of a managed care based health system called TRICARE. The Military Health System (MHS) changed significantly with the implementation of TRICARE. In 1996, MACH converted its third floor Intensive Care Unit into a TRICARE Prime Clinic (TPC). The physical design and layout of MACH has remained relatively unchanged from its days of inpatient-focused care. As the mission of the hospital shifted to an outpatient focus, clinical services have changed or shifted locations in the facility, without any significant redesigns of the facility for the services. As a result, the facility's physical layout contributes to less efficient operations.

MACH has 17 specialty clinics and 2 outpatient primary care clinics that recorded over 218,617 patient visits in FY 2000. MACH has an enrollment population slightly over 28,000 that accounted for 85,588 primary care visits in FY 2000. The General Outpatient Clinic (GOPC) and the TRICARE Prime Clinic (TPC) each have an enrolled population of 14,000.

In FY 1995, the Fleet and Industrial Supply Center (FISC) contracted with Sentara Health Systems to operate a NAVCARE clinic (TPC) on the third floor of MACH. Sentara provided the staffing and operated the clinic independently with the task of caring for TRICARE beneficiaries. MACH operated the GOPC on the first floor to care for the active duty population and other TRICARE enrollees. In 1999, the FISC did not renew the contract with Sentara because 32 CFR part 199.17 prohibits more than one contractor to be at risk in a region. By this time, Anthem Alliance of Health Inc. had become the primary TRICARE contract holder for Region Two (Zeto, 1999). On 1 October 1999, MACH assumed the responsibility of staffing and operating the TPC.

Since taking over the TPC, primary care operations have been disjointed. Providers routinely start the day in the GOPC seeing sick call patients, then transition to the TPC at 0900. TPC operations are from 0900 to 1700 and TPC enrollees can still obtain an appointment after 1700, but are seen in the GOPC. Providers must then move down to the GOPC after 1700 to see the evening cases. In addition, the TRICARE Management Activity (TMA) directed the implementation of the Primary Care Manager By Name Program (PCMBN) to improve continuity of care. PCMBN assigns patients to a panel of providers and a primary care manager. This is a positive action that, if successful, will improve the quality of care to our beneficiaries. The implementation of PCMBN coupled with the current state of primary care operation makes consolidation of operations a logical management decision.

Statement of the Problem

MACH leadership is faced with the same dilemma of limited monetary and physical resources that constrain most MHS Military Treatment Facilities (MTFs). Access and space are critical issues dealt with on a daily basis. Operating two clinics as described in the introduction reveals several operational inefficiencies. The consensus among the leadership is that consolidating the GOPC and TPC clinics will improve operational efficiency and access. This study serves as a tool to evaluate the validity of this consensus focusing on two distinct areas: Capacity and operational efficiency. A scientific evaluation will determine if the 3rd floor has sufficient capacity to handle the expected demand. Capacity is defined as the ability for the proposed floor plan to accommodate the current appointment demand at or less than current processing times. Two floor plan designs evaluate the potential capacity and associated costs. Estimated costs for construction ranges from $15k-$300k, depending upon the floor plan chosen. If capacity is sufficient, the next question is one of efficiency. More specifically, what is the appropriate mix of screening rooms, exam rooms, treatment rooms and staff for the new clinic? In this circumstance, efficiency refers to the length of time it takes for the patient to get into the exam room to see a provider and time between when the patient arrives and when the examination is complete. Computer simulation model is a method to quantitatively evaluate proposals before committing valuable and scarce resources to a project and is a proven analysis tool.

Literature Review

The origin of systematic models has no real known origins. The most basic form of modeling known is through the graphic use of symbols to represent relationships between components in a system or activity. It is difficult to identify a single professional or technical discipline that does not use some form of modeling. Before computers, model complexity was restricted by the mathematical capabilities of the modeler. Time and resources to create models grows exponentially as the mathematical complexity increases. The study of nuclear chain reactions by the Manhattan Project required the mathematical genius of individuals like Albert Einstein to successfully model a nuclear reaction. With the technology of today, the dependence on mathematical genius is no longer a requirement. (Bateman, Bowden, Gogg, Harrel, & Mott, 1997).

Simulation is the experimentation of a detailed model of a system to test how the system will respond to changes in its process, environment or underlying structure. In a healthcare environment, the facility floor plan and the staff make up the major components of a self-contained healthcare system. In the 1960's, IBM introduced the first automated queuing simulator. Since then, the advancement of the microcomputer has introduced spreadsheet and graphic simulation models. The increase in computer availability directly reflects the increased interest to use computer simulation techniques to conduct operational analysis (Austin & Boxerman, 1995). Software flexibility and increased processing speeds now enables simulation software to handle very complex and dynamic systems with very accurate results (Bateman et al., 1997).

General Systems Theory is the understanding of an entire process and how parts in a system relate to each other in the system's objective. Management must evaluate performance of a system, compare this performance against expectations, and use this information to sustain or improve the system (Austin and Boxerman, 1998). Continuous Quality Improvement (CQI), a concept derived from Deming's Total Quality Management principles, is a popular buzzword in healthcare based upon General Systems Theory. Using CQI, managers evaluate a system and seek to improve results by influencing the process. There are many ways to evaluate a process, but only a few ways to both evaluate and predict the effect of a change in the process. Managers that are able to accurately predict the effect of a change will maintain a higher level of system productivity in most cases. Computer simulation enables a manager to model a system and test various “what if” scenarios (Bateman et al., 1997).

Computer simulation is not always the most appropriate method to conduct operational analysis. Additional training is required for the users of the software and time must be provided to the users to complete the project. In situations that require a decision of a systematic process that may require large amounts of time and manpower to complete, computer simulation provides the following benefits:

1) Problem Identification. Computer simulation demands a thorough investigation to define the problem, avoiding the pitfalls of guessing or swaging. In addition, simulation forces the evaluation of the dynamics of a system’s processes.

2) Development of an Analysis Method. Simulation has a track record of success as a tool to analyze problems. Once again, simulation demands a well-defined method to analyze the problem, avoiding the pitfall of guessing.

3) Computer Coding. Computer simulation removes the time necessary to develop and write extensive computer programs to analyze and present data. Simulation programs are advanced to the point where the user involves minimal programming requirements.

4) Spreadsheet Analysis. Simulation has pre-programmed report and analysis functions, allowing the bypass of creating spreadsheets to analyze results.

5) Opinion Modeling. The use of simulation forces the user to collect empirical data, avoiding the use of opinions or “gut-feelings” to represent critical events in the model. The use of empirical data adds to the reliability and validity of the model.

6) Trial and Error Experimentation. This is one of the most powerful reasons to use computer simulation. Users can easily conduct “what if” scenarios to test changes in the system with minimal or no operational impact on the actual system (Bateman et al., 1997).

Computer simulation has evolved over the past decade as an effective operational analysis tool in healthcare. Simulation in healthcare is best utilized to evaluate management decisions concerning patient flow, appointment schedules, staffing, and facility capacity. These major areas directly reflect on how many patients can be seen and how long treatment may possibly last. Both are critical to staying in business and maintaining customer satisfaction.

In 1996, the University of Mexico was able to improve patient flow in its Internal Medicine Clinic using simulation. Before the study, a patient spent 75 minutes in the clinic. A computer simulation analysis recommended an adjustment in staffing and internist scheduling that resulted in a significant decrease (*t* test, $p < .001$) in total patient time in the clinic to 57 minutes (Hashimoto & Bell, S., 1996). Using simulation, the university was able to look at patient arrival patterns, treatment times, and staffing mixes to determine what operational changes had the desired results.

The United Kingdom’s universal healthcare system offers unique challenges of high utilization. The cost for healthcare in the United Kingdom has escalated in similar fashion as the United States. To maintain control of costs, resources must be used judiciously. A common problem in the United Kingdom's system is long waiting lists for specialty care, partially caused by the "recycling" of patients, which limits the number of appointments available for new patients. In order to limit the disruptiveness of a major change in clinical practice, the University of Liverpool conducted a computer simulation analysis to test recommended changes in a Urinary Clinic. The United Kingdom's analysis focused on physician staffing, distribution of appointment types, and patient arrival intervals. The study demonstrated that by spreading new appointments throughout the day, patient-waiting times decreased. (Clague, Reed, Barlow, Rada, Clarke, & Edwards, 1997).

The previous two examples of simulation were conducted in a non-graphical environment. Non-graphical means that there is not any visual evidence of the clinic operations, just computer generated data. A more recent innovation in healthcare simulation is Monte Carlo Simulation. This provides a graphical depiction of the simulation. The MedModel software is based upon Monte Carlo Simulation. The software has a menu-driven interface that is user friendly. In recent years, MedModel has become the U.S. Army's software package of choice to conduct healthcare operations analyses. Training on the program is offered in the Army-Baylor Program in Healthcare Administration and has been used in several projects across the Army Medical Department.

In February 2000, Military Medicine, published an operational study of a Dental Clinic in Germany using MedModel. The study conducted "what if" analyses on the clinic to determine the most appropriate staffing mix of dentists and receptionists from the perspectives of cost, quality and access. Cost is evaluated by total staff salary; access is evaluated by the average daily throughput; and quality is evaluated by a ratio of total treatment time to total time in the clinic. The authors point out that quality is difficult to quantify, but makes the assumption that lower waiting times result in greater satisfaction scores. The study evaluated six scenarios of various dentist and receptionist staffing mixes. As expected, the scenario with the highest staffing level, 2 dentist and 3 receptionists, had the best scores for access at 28 per day and quality at 17%, but cost the most at $590,000. The scenario with a staffing mix of 1 dentist and 3 receptionists had the next best score for access and quality, 23 per day and 13% respectively, and a modest cost of $340,000. When compared with the current operations of 1 dentist and 1 receptionist, access of 10 per day, quality of 6.8%, and cost of $280,000, the appropriate decision becomes more evident. The clinic can double throughput and increase patient satisfaction by 100% with an investment of an additional $60,000. The objective of this evaluation is to determine the most efficient use of resources. The investment of $310,000 additional dollars does not justify the 5% increase in quality. Instead, the clinic may consider alternate, less costly, methods to increase patient satisfaction, such as improving aesthetics of the clinic (Montgomery, LaFrancois, & Perry, 2000).

Decision-making in today's healthcare environment is a very risky and complex process. Managers and administrators require decision support systems to aid in justifying decisions. Computer simulation has evolved into a very reliable method to evaluate operations in a variety of healthcare setting. Simulation also helps prevent making several changes in the work environment and process before getting desired results. Constant tinkering in the process of care will decrease staff satisfaction, disrupt operations and can ultimately cost the organization valuable financial and human resources. A well thought out computer simulation analysis provides a less costly, less disruptive, and proven method to make operational healthcare decisions.

Purpose

The purpose of this study is to evaluate the feasibility of consolidating primary care services and its impact on patient access and operational efficiency. The use of a computer simulation model will allow the MACH leadership to see the impact of this decision in advance of making any significant changes. The objective of this study is to evaluate two proposed clinic configurations. Each configuration shall be evaluated on potential capacity and the efficiency of the patient care process. The recommended solution will be presented to the hospital leadership and the Health Facility Planning Agency to be considered in the MACH facility Master Plan.

Methods and Procedures

General

MedModel, a software package developed by ProModel Corporation, is the analysis tool for this project. Computer simulation is a unique and relatively new method to quantitatively test hypotheses in healthcare settings. ProModel Corporation recommends the following steps for successful computer simulation: Establish goals and objectives; formulate and define the model; collect data; build, verify and validate the model; and experiment, analyze and present results (Bateman et al., 1997). This study will follow this format. Appendix A illustrates the study process.

Goals and Objectives

The goal of this project is to determine the most efficient way to operate the proposed consolidated clinic. A secondary goal of this project is provide input for a floor plan to be funded as a part of the Master Plan Review.

Four objectives are identified in order to achieve the above stated goals:

1. Determine if any proposed clinic floor plans have sufficient capacity to meet the current demand for a combined population of 28,000 TRICARE Prime beneficiaries.

2. Evaluate floor plans with sufficient capacity for appropriate mix of screening rooms, exam rooms, treatment rooms, and staffing.

3. Evaluate the feasibility of screening patients in the exam room.

4. Provide a recommendation to the MACH leadership.

Formulate and Define the Model

Model formulation began in December 2000. Meetings were conducted with the Chief of Primary Care, Chief of the TRICARE Prime Clinic, Head Nurse of the TRICARE Prime Clinic, Chief Nurse for the Department of Primary Care, Deputy Chief of Logistics and a Facilities Planner to discuss clinic processes, staffing requirements and floor plan options. The flow chart in Appendix B defines the patient care process for the consolidated clinic. This flow chart serves as the foundation for the model. In addition, four patient types were defined: A primary care; physical examination, pelvic examination; and a same day follow up patient. Different patient types were chosen due to their unique resource requirements and arrival patterns.

Identifying a floor plan design is a critical step in the planning process. The Chief of Primary Care and the Facility Planner assisted in the development of two floor plan designs. Two contrasting floor plans provided an economical approach and a more elaborate and ultimately more expensive approach. Each floor plan was evaluated using an option to screen patients in a dedicated screening room or screen in an exam room, eliminating the need for screening rooms. See Build, Verify, and Validate the Model for more detailed information regarding floor plans.

Collect Data

The MedModel program is an event based simulation analysis tool. Therefore, the model requires data that drives the duration of specific events in the patient care process. The patient care process in Appendix B shows that the simulation requires time data on the following events: Reception check-in, screening, examination, treatment procedures, and patient discharge. Data was collected through three sources: Time and Motion Study, the Composite Healthcare System (CHCS), and interviews.

A time and motion study was conducted using the instruments shown in Appendices C and D. Clinic staff was briefed a week prior to data collection and a two-day test was conducted to identify and correct shortcomings in the data collection process. Data collection commenced from January 22-26, 2001 after a successful test period. The time and motion study provided a sample of 234 patients. This provided data for reception check-in, screening, and exam times. The time and motion study also provided data about the frequency of same day follow up patients and how many patients arrive without medical records available at time of check-in. These items are critical in determining the duration of time the patient spends at different points in the patient care process and adds to the validity and reliability of the model. This data also provided two critical benchmarks to measure the models against: Time to Provider (TTP) and Time to Complete Exam (TTCE). TTP is defined as the length of time it takes the patient to get into an exam room to see a provider. This is the difference between the exam start time and the scheduled appointment time. MACH's current TTP is 18 minutes. TTCE is defined as the length of time it takes the patient to complete the examination. This is the difference between the exam end time and the scheduled appointment time. MACH's current TTCE is 44 minutes. These benchmarks will determine if sufficient capacity exists and what the better solution may be.

CHCS is the Department of Defense's automated patient care system. This system provided the patient workload data that drives the model. CHCS end of day reports from February 5, 2001 to March 2, 2001 determined the daily patient arrival cycles for the typical primary care patient and physical examination patients. Data are sorted by day of the week and the frequencies of arrivals are broken down by the hour between 0845 and 1700. This provides an arrival cycle for each day of the week. CHCS also provided data reflecting the quantity of telephone consults (T-CON) the reception staff receives and enters for providers during the day. Arrival cycles for T-CONS are derived in the same way as patient arrivals. See Appendices E, F and G for workload information.

Collection of data to represent treatment times was a bit more challenging. The TPC clinic maintained a log of procedures by type and duration but the GOPC clinic did not. Fortunately in March, the Head Nurse of the GOPC implemented the same system as the TPC clinic to collect treatment data. By the end of March one months worth of data was available to reflect the number of procedures, types of procedures, and duration of procedures. The data from the two clinics were combined and sorted by procedure type to determine the percentage of total visits required a procedure and approximate duration by procedure types.

Interviews provided the final source of data. There are some events that data are not readily available or easily collected, therefore interviewing the users in the system assist in making educated assumptions. One such situation is for patients requiring pelvic exams. It so happens that the GOPC and TPC clinics plan on conducting pelvic exams to assist in the backlog that currently exists in the Womens Health Clinic (WHC). The process of care, quantity to be processed, and duration are all based upon conversations with the clinic personnel. Chaperoning is another event that data are not easily obtained. Interviews with the support staff provided the foundation for an assumption on the frequency and duration of chaperone duties. The other aspect is record generation waiting times for patients that do not have a record. Interviews with the reception staff determined that the time could range from two minutes to twenty minutes depending how long it takes to track down the record or if the Outpatient Medical Records Section needs to generate a new record. A final, but critical aspect of the model, based upon interviews, is the discharge process. The Deputy Commander for Nursing, Assistant Deputy Commander for Nursing, and the Head Nurse of the TRICARE Prime Clinic provided vital information on the discharge process.

Build, Verify, and Validate the Model

Four models were built using MedModel. For identification the models are titled as follows: Current Floor Plan With Separate Screening Rooms (Model 1); Current Floor Plan Without Separate Screening Rooms (Model 2); New Floor Plan With Separate

Screening Rooms (Model 3); and New Floor Plan Without Separate Screening Rooms (Model 4). Floor plan illustrations are found in Appendices G, H, I and J.

Model 1, the first model developed, has 20 exam rooms and up to 8 screening rooms. Model 2 is similar to Model 1, except that screening occurs in the exam rooms, and adds two exam rooms that were screening rooms in Model 1. Models 1 and 2 require minimal construction, estimated cost between $15k-25k. Models 3 and 4 process the same as their sister models based upon the current floor plan. The main difference is in the floor plan designs. A total of 28 exam rooms are in the new floor plans as well as an additional hallway to navigate. Models 3 and 4 require extensive construction, estimated cost between $250 – 300K. The analysis phase should provide some data on how changing the floor plan effects the over all results.

Verification and testing for validity in computer simulation is accomplished in two ways: Compare the status quo or a status quo model with alternative models; and technical evaluation for face validity by a panel of experts of the system under study. Status quo validation is most appropriately used when modeling an existing system or process. Technical expertise is appropriate when the system under study is a new concept and there is not a base line from which to draw a comparison (V. Lang, personal communication, November 30, 2000). Validity is tested using both methods. A comparison of 212 daily visits for the month of February 2001 and the average of 218 visits of the model run over six months shows that the model produces daily workload within a very close margin.

A PROMODEL Corporation Consultant provided validation of the models through technical expertise. The consultant proved very valuable in modeling complex processes that helped to obtain the best results in the project. A major improvement to the model during the verification process was the incorporation of teams, resembling the PCMBN program. This process is modeled by creating three teams of providers and support staff. Exam rooms are divided and assigned to each team. Patients are assigned to a specific team upon arrival. Using this configuration will allow an analysis of how many providers, support staff, and exam rooms are required per team.

The following members of the staff provided face validition: Hospital Commander, Deputy Commander for Clinical Services, Deputy Commander for Administration, Chief of Primary Care, Chief of Primary Care Nursing, Chief, Clinical Operations Division, and Head Nurse of the TRICARE Prime Clinic. The validation process consisted of a detailed walk through of the models components, data collection, and methodolgy used to build the models. All provided valuable input into the final models and found the model to be valid based upon face value.

Experiment, Analyze and Present Results

The analysis part of a computer simulation project provides the substance from which a decision can be made. The analysis for this project is broken into four phases: Model optimization with the SimRunner software package; comparing models with optimization settings; conduct scenario analysis to find a solution; and option comparisons.

SimRunner is a computer program created by ProModel Corporation to evaluate models for potentials best-case solutions. Optimization is a technical way of saying “what if” analyses. During the model development process macros are created that allows SimRunner to change the number of predefined locations and resources.

Locations are defined as screening rooms, exam rooms, and treatment rooms. Resources are defined as the receptionists, provider teams, support staff teams, and treatment room staff. Inputs used in each model are found in Appendix M. A predefined range for locations and resources gives SimRunner an upper bound and lower bound to use in the optimization process.

The second step in the optimization process is to define outputs. Outputs are those things that help answer the research question. The optimization process is a mathematical equation. Each of the selected outputs is given a numeric weight to determine what outputs are more important than others. This is critical because improper weighting will make any results inaccurate. See Appendix N for an example of outputs. In this case, we want to know what space and staff is required to optimally run the clinic. A close analysis of appendix N will reveal prefixes of MAX and MIN followed by a number. MAX represents to maximize and MIN represents to minimize. The number is the selected weight for the chosen output. Maximization of Utilization Percentage is an excellent indicator of how well the models use locations and resources. To just maximize locations and resources without regard to the patients in the clinic would be a fatal flaw in the analysis. Therefore, it is important to minimize how long it takes the patient to process through the clinic. With this in mind, all locations are weighted the highest at 5. All resources are weighted at 4.5, followed by TTCE at 4, how long the patient waits for staff at 3, and TTP at 2.5.

The next step in the optimization process is to set the number of repetitions and run the model. SimRunner proceeds to run numerous experiments, varying the inputs chosen, in order to determine what the optimal solutions are. SimRunner conducted

154 experiments for Model 1; 110 experiments for Model 2; 329 experiment for Model 3; and 407 experiments for Model 4. The optimization process can take between several hours and several days, depending on how many inputs are selected. For this project, the longest optimization process lasted approximately 30 hours. SimRunner produces two types of results: The top ten solutions and a spreadsheet that lists every single experiment with the inputs used in each experiment along with the results for the selected outputs. Appendix O provides an example of the top four solutions SimRunner found for Model 1.

The final step is to determine which SimRunner solution to use as the optimal solution. Choosing the top solution is not necessarily the best solution. A comparison of the average of the top 25 solutions, top ten solutions, top three solutions, and the top solution narrowed down the optimal solution. Appendix P shows the optimal results chosen for each model using this methodology. A quick review of the results reveals that there are similarities in the staffing solution for all models. The main differences are the number of receptionists and exam rooms. Models 3 and 4 recommended a total of 24 and 26 exam rooms respectively, while models 1 and 2 recommended 17 and 19 exam rooms respectively. This difference may be the result of the difference in floor plans. A comparison of models will reveal if any significant differences exist.

In order to conduct a comparison of the four models, the optimized solution is programmed into the model and an experiment is ran over a period of six months and several replications. Models 1, 2, and 3 required five replications and Model 4 required eight replications. Appendix Q provides an example of the calculation of replications required to provide a 95% confidence interval that the benchmark of TTCE is within acceptable limits. Once the replications are complete, the selected outputs are compared. MedModel produces a statistical output file that shows critical statistics on how often locations and resources are used. Comparisons are accomplished by charting out results found in the MedModel Output File.

As mentioned earlier, Utilization Percentage is a good indicator to evaluate the usage of locations and resources. A Utilization Percentage of 70% for Exam Room 1 indicates that Exam Room 1 was occupied 70% of the time. As the model runs, locations are selected in a hierarchical fashion. For example, there are six exam rooms available to team one and each are given names Exam Room 1, Exam Room 2, Exam Room 3 and so forth. When the model determines which exam room to use, it always starts with Exam Room 1. If it is not available it checks Exam Room 2 for availability and on down the line. When the results are charted, a stair step design is produced showing how utilization drops off with more locations to choose from. As utilization decreases across locations it becomes apparent when you reach a point of diminishing returns.

Resource Utilization Percentage is very similar to locations, except that utilization indicates anytime a resource is in transit or in use. Since it is impossible to model every single task resource accomplish during a typical workday, one must not mistake the idle time as unproductive time. This idle time also includes the completion of administrative tasks not captured by the model. Analysis of utilization percentage for resources is the same as for locations.

Appendix R shows the charted results of location utilization percentage. This shows how the optimized models compare to each other. Models 1 and 3 each show very similar utilization in screening rooms and exam rooms. The same can be stated for Models 2 and 4. Models 2 and 4 have higher Utilization Percentage due to the fact that the exam rooms are used as screening areas, therefore are used for longer durations compared to Models 1 and 3. Treatment room utilization is very similar; Model 1 deviates from Models 2, 3 and 4 only because an additional room is used. None of the models appear to have any significant advantages in the utilization of exam rooms. Appendix S shows the charted results of Resource Utilization Percentage. Receptionist utilization is low for all four models, none demonstrating an advantage. Provider utilization is the same for all models with the exception of Provider Team 1 in Model 2. This is due to the fact that Model 2 has four providers on Team 1, while the other models have three providers on Team 1. The same situation exists for the utilization of treatment room staff with Model 2 having one more member assigned to the team. It is very difficult to draw any conclusion from the chart that compares the Utilization Percentage for Support Teams. The differences in the number of available exam rooms, providers across teams, and support staff across teams causes the charted results to vary significantly. The variation does show how sensitive the support staff is to changes in the available locations and providers.

Up to this point, all of the models appear to be very similar as far as Utilization Percentage comparisons are concerned. Comparison against the TTP and TTCE benchmarks may provide a clearer picture of how effective the models are. Figure 1 presents the model comparisons of benchmarks.

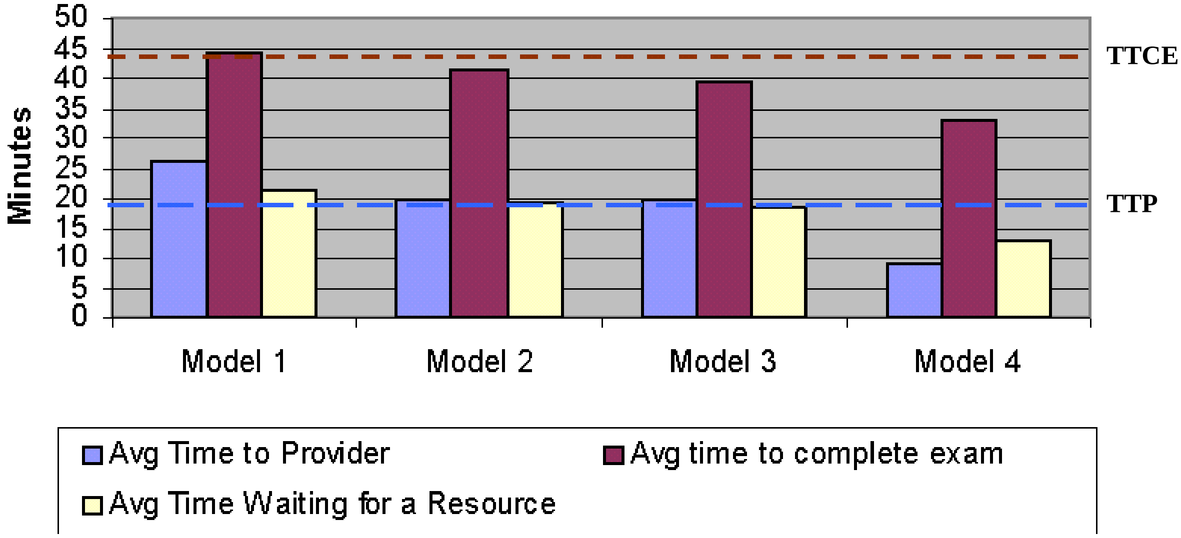

Figure 1. Model 1 fails to meet the benchmarks, while the remaining models are able to meet the benchmarks. Model 4 appears to be the best solution, since it has the most providers and exam rooms than the other models.

Comparing benchmarks in this situation is not very effective in determining which model is a better solution. The variation in staffing and exam rooms between models makes this analysis like comparing apples and oranges. This analysis makes it clear that the 3rd floor should have the capacity to handle the current demand of both primary care clinics. The only question remaining is what is the best solution. Conducting a scenario analysis on the models will help answer this question.

Scenario analysis is the process of making incremental changes in the model settings and observing the effect on the critical benchmarks. This analysis introduces an additional performance measure, Average Time Waiting for a Resource, which is a cumulative measure of how long the patient waits. Figure 2 shows the scenario analysis for Model 1.

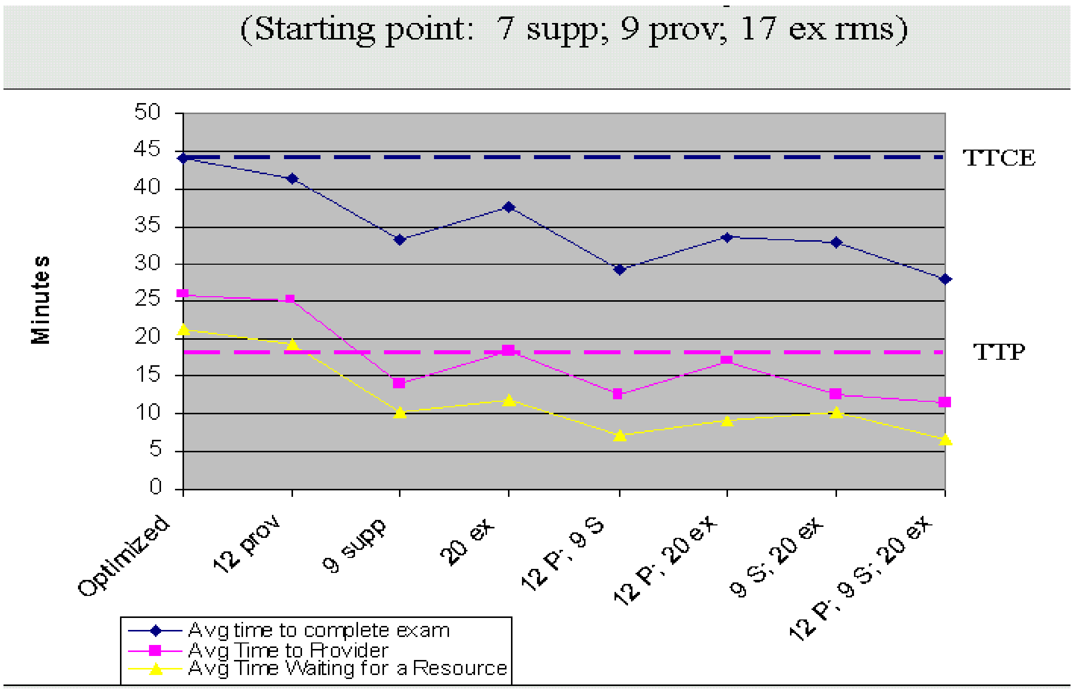

Figure 2. Scenario analysis of performance benchmarks on Model 1.

The analysis shows the effect of adding only providers, only support staff, only exam rooms, and combinations of all three. By adding three providers, there is a small decrease in the benchmarks, but if you add two support personnel, over ten minutes is shaved off all benchmarks. It is also interesting that the addition of two exam rooms is not as effective as adding support staff.

Model 1 demonstrates that with the appropriate staffing, it can easily support the demand. In addition, adding exam rooms does not provide any distinct advantage. Figure 3 shows the scenario analysis for Model 2.

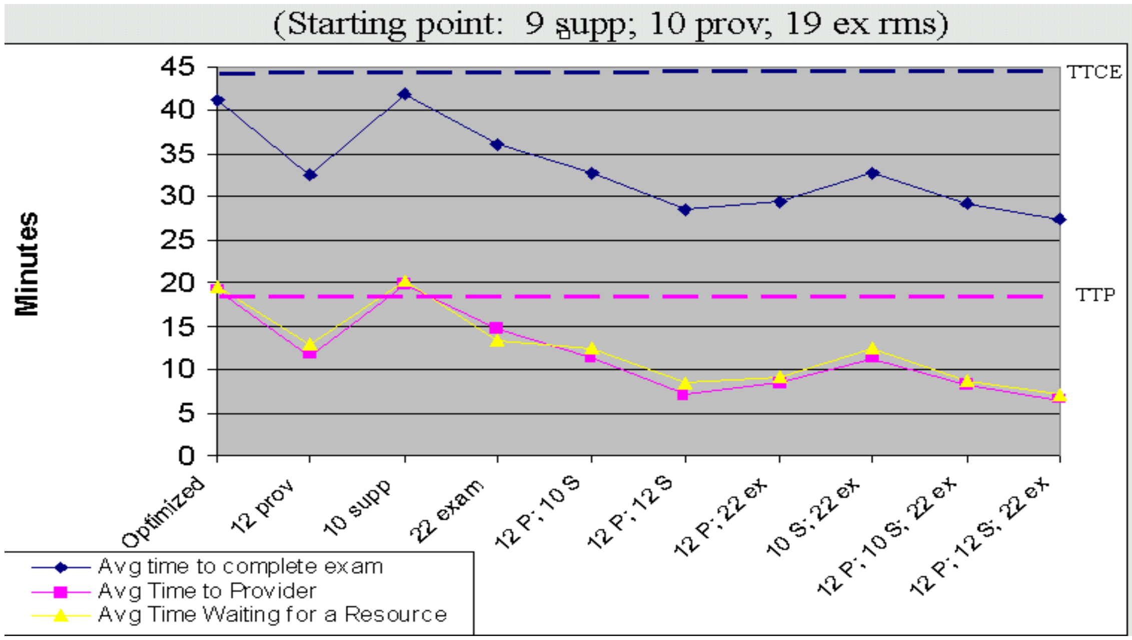

Figure 3. Scenario analysis of performance benchmarks on Model 2.

An analysis of Model 2 shows that the incremental changes have similar effects as in Model 1. The main difference is that adding three providers decreases the benchmarks by eight minutes, while there is a small gain in the benchmarks with the addition of one support person. This is due to the fact that in Model 2 screening is occurring in the exam rooms. The exam rooms are full with patients waiting for a provider and there is no space available to allow the support staff to screen the patients. When providers are added, these exam rooms are cleared out quicker, but adding support personnel without additional providers provides no relief. Adding additional exam rooms does provide some benefit, but does not provide the greatest benefit without adding more staff to support the additional exam rooms.

This analysis clearly shows that a floor plan with fewer than 20 available exam rooms can meet the current demand requirements, but screening in the exam rooms does not provide any real benefit without additional exam space and staff. Figure 4 shows the scenario analysis for Model 3.

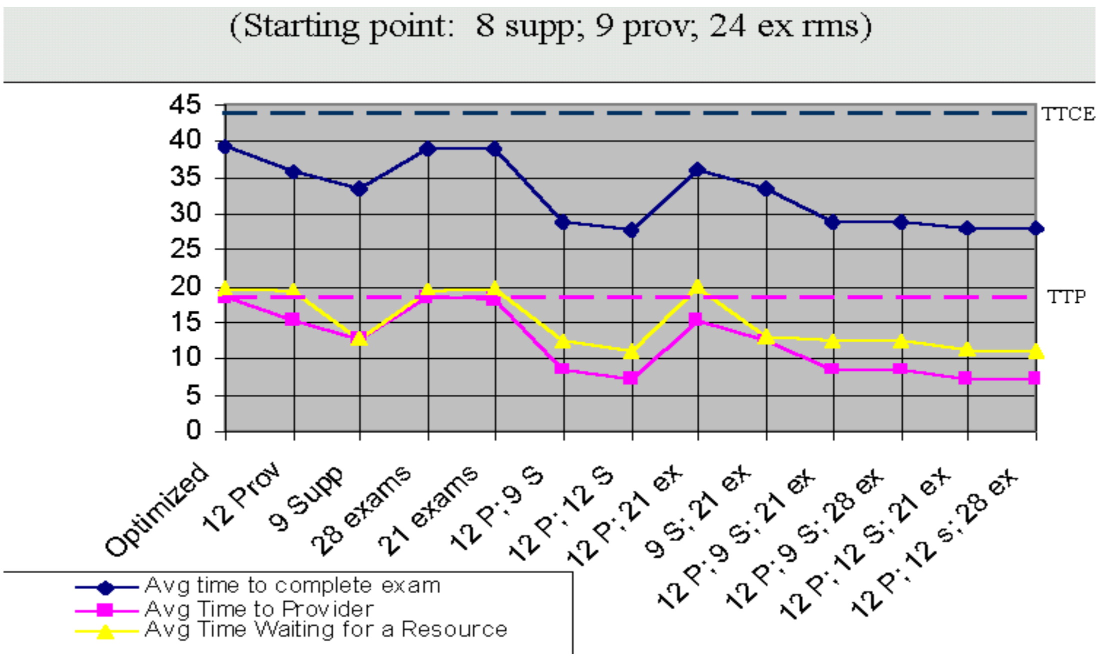

Figure 4. Scenario analysis of performance benchmarks on Model 3.

Model 3 has a larger floor plan and required more scenarios than the previous models. The results are very similar to Model 1. Staffing has a more significant impact on the benchmarks than exam rooms. An interesting finding is that there is no difference between 21 and 28 exam rooms, anything over 21 provides no gain in the operations of the clinic. Figure 5 shows the scenario analysis on Model 4.

The results are very similar to Model 2; both conduct screening in exam rooms. Again, adding three providers gives the greatest benefit; adding support staff provides

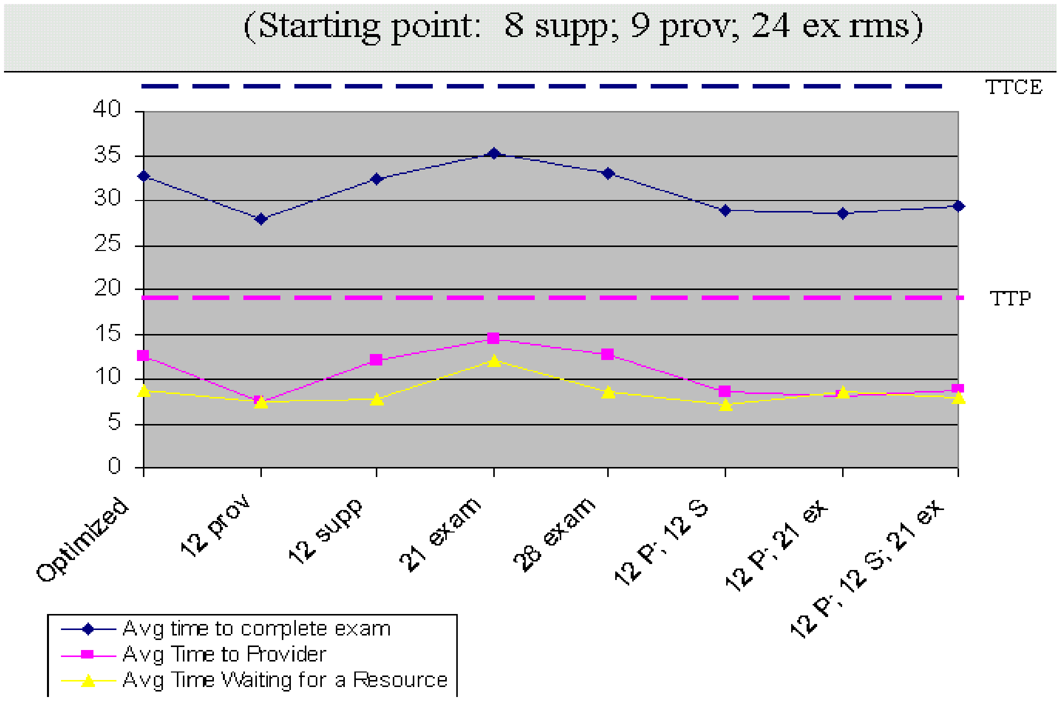

Figure 5. Scenario analysis of performance benchmarks on Model 4.

no gain. The effect on exam rooms is the similar as well with very little difference between 21 and 28 exam rooms. Once again we see that when screening is conducted in the exam rooms, appropriate staffing is critical to its success. In addition, it is clear that anything above 20 exam rooms provides little benefit in the performance benchmarks.

The only way to truly compare the models is to use the same settings and compare the results. Current operations provide 18 exam rooms and an average of 9 providers available each day. With this in mind, Option 1 is to use a total of 9 providers, 9 support staff personnel and 18 exams. Option 2 is to increase these to 10 providers, 10 support staff personnel and 20 exam rooms. A similar comparison and analysis of these two solutions should reveal a realistic solution.

Appendix T and U shows the charted results of Location and Resource Utilization Percentages for the two possible solutions. The results are virtually the same across all the models as should be expected. Again, Models 2 and 4 have higher location utilization due to the fact that screening is occurring in the exam rooms. The main point of emphasis is that there is no difference in utilization between any of the models when compared with equal settings. Using the benchmarks from the previous scenario analyses provides a better indication of the models' performance. Figure 6 shows that

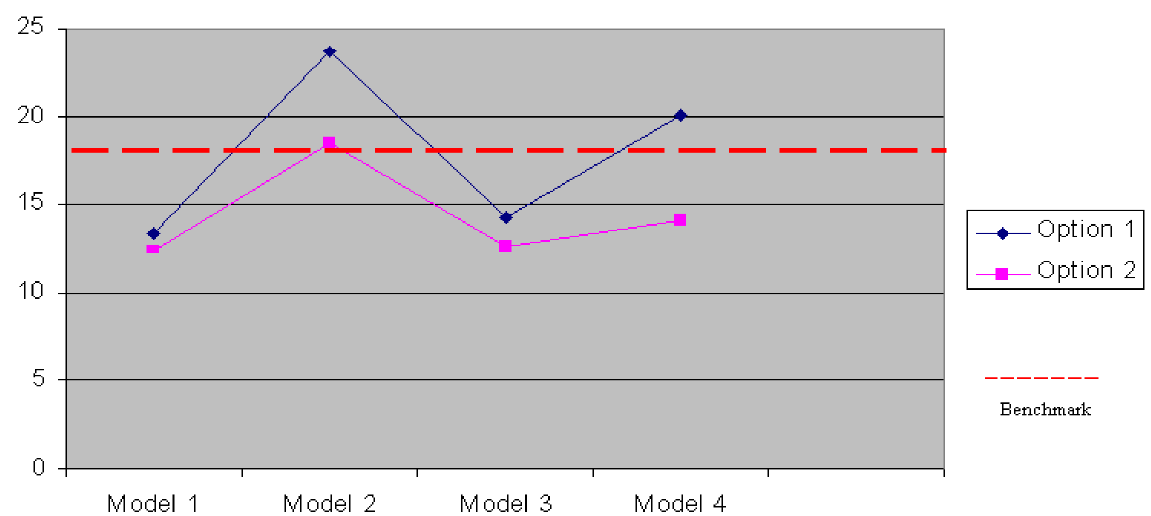

Figure 6. Benchmark comparisons for Average Time to Provider.

Models 1 and 3 are able to pass the benchmark for TTP in both solutions, with Model 1 having the best over all results right at 13 minutes to get the patient into see the provider. Model 2 never passes and Model 4 needs the extra exam rooms and staffing in order to be acceptable. This trend is consistent with the bottleneck created when screening is conducted in the exam rooms. Figure 7 shows very similar

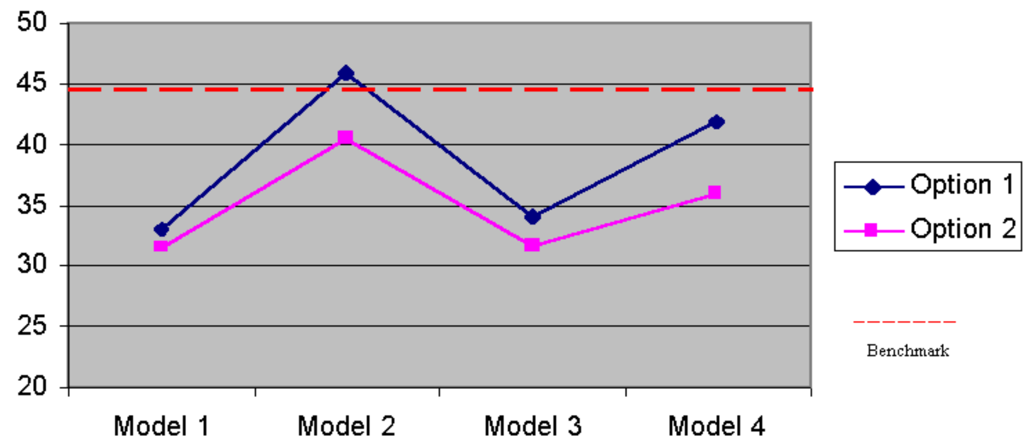

Figure 7. Benchmark comparisons for Average Time to Complete Exam.

results. Models 2 and 4 perform somewhat better, but are unable to perform as well as Models 1 and 3. The final performance indicator to compare is the Average Time Waiting for a Resource found in Figure 8. The trend lines look basically the same as the two previous figures. Although there is not an established benchmark, it is clear

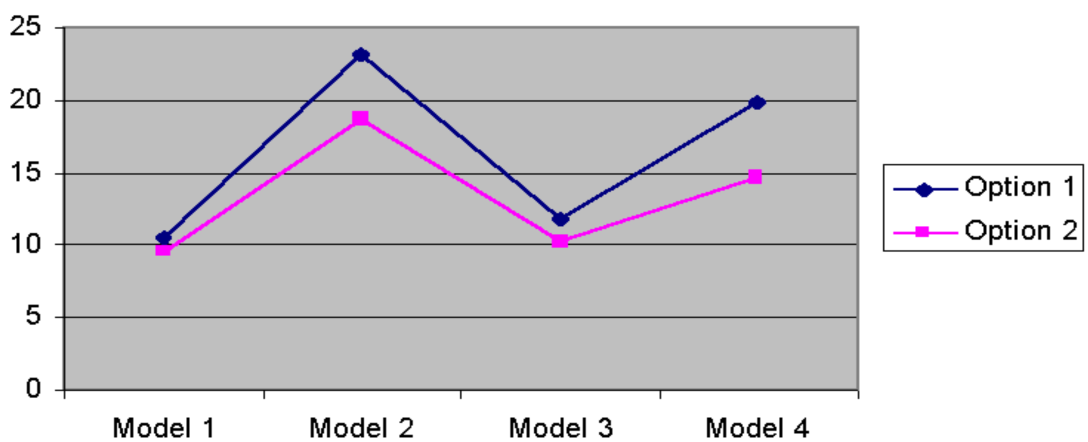

Figure 8. Comparisons for Average Time Waiting for a Resource.

that Models 1 and 3 provide less waiting times by at least five minutes compared to Models 2 and 4. This final analysis demonstrates that a floor plan with 18 exam rooms is capable of handling the workload for a consolidated clinic and that the best results are realized when screening is conducted in separate screening areas.

Discussion

MACH opened in 1964 as a 116-bed inpatient facility in an era dominated by episodic care focused around treating illness in a hospital setting. Fast-forward 36 years where healthcare is in a new era dominated by managing health and controlling the escalating cost of treatment. Today's era is outpatient services with a focus on primary care. MACH now finds itself scaled down to 30 beds that rarely ever have more than 10 of the beds filled. Significant resources have been expended over the years to shift the facility into an outpatient service center. This shift to a primary care focus has been and continues to be a challenge to MACH and other facilities in the MHS. Limited space and monetary resources increases the challenge of balancing fiscal responsibility and the needs of the community. All services in the facility are under constant scrutiny to seek efficiencies in operations. The consolidation of primary care on the 3rd floor is a combination of trying to seek out efficiencies and improve the service provided to the community.

Anytime an organization makes a decision concerning its most valuable product line, the decision making process should not be made hastily without researching the problem. Quantitative decision making methods exist to allow significant organizational decisions to be made based upon data rather than gut instincts. Computer simulation is one such decision support system to aid in the decision making process. Literature supports the use of computer simulation as an effective decision making tool. MedModel was employed in this circumstance to determine if the 3rd floor is capable of handling the workload demand and what are potential solutions for the layout of the clinic and required staffing levels. An analysis of four possible floor plans and two patient care processes demonstrated that primary care operations could be consolidated on the 3rd floor at current levels of demand. In addition, it demonstrated that screening in exam rooms is not an option unless there are more than 20 exam rooms and additional staffing to support these added rooms. Adding additional exam rooms similar to the floor plan in Models 3 and 4 to the 3rd floor required a major reconstruction project at an estimated expense of $300,000. The analysis also revealed that there is not a significant gain in efficiency beyond 21 exam rooms. It does not make logical or economic sense to build an extravagant floor plan, if small modifications at a much smaller expense can meet the needs of current workload requirements.

The results of this computer simulation analysis found that the optimal solution is to have 18 exam rooms, 5 screening rooms, and 3 treatment rooms. This supports current demand at current provider staffing with an average of nine providers on duty each day day and cost avoids the hospital approximately $275-$285K. The results were presented to the hospital leadership in May 2001 with the recommendation to have the space committee propose a floor plan in line with the recommendation of this project.

Conclusion

Computer simulation is one of many quantitative support systems available to healthcare organizations. A project involving simulation requires a commitment by the organization in the form of manpower, time, and training to ensure the final product is worthwhile. The current financial situation in healthcare and the MHS almost demands decisions be data driven. Computer simulation is an excellent method to predict future needs. Settings are easily adjusted to reflect increased demand. This makes the utility of the models extend beyond this project. The MHS transitions into the TRICARE for Life Program in October 2001. This is a significant event that will undoubtedly place a greater demand on the already over extended MHS. The use of computer simulation can be used as a predictive tool on how the increased demand will affect the healthcare system. Modeling can easily be used to determine at what point do current resources reach capacity before a major financial decision must be made. In an age dominated by information systems and resource constraints, organizations should consider computer simulation as a decision support system.

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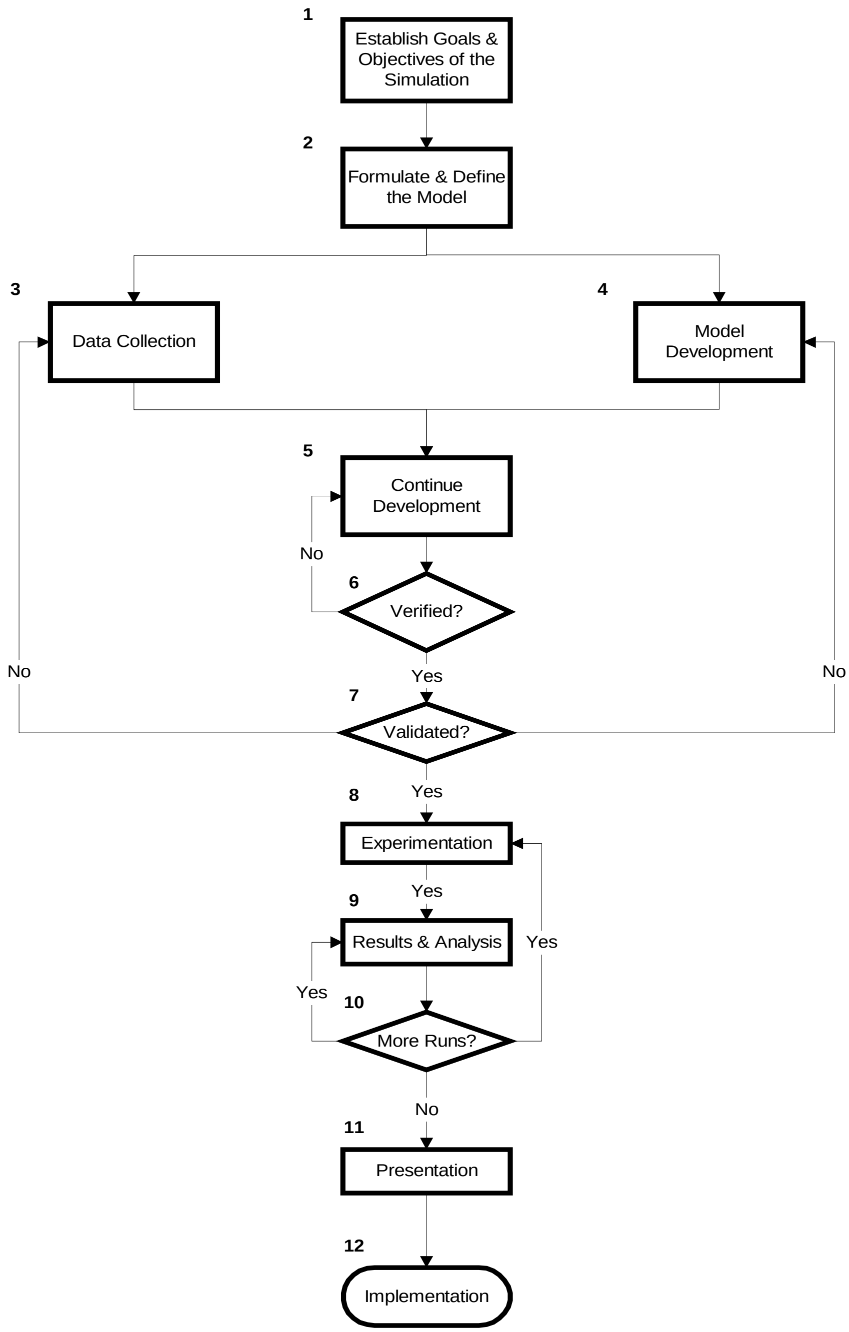
Appendix A

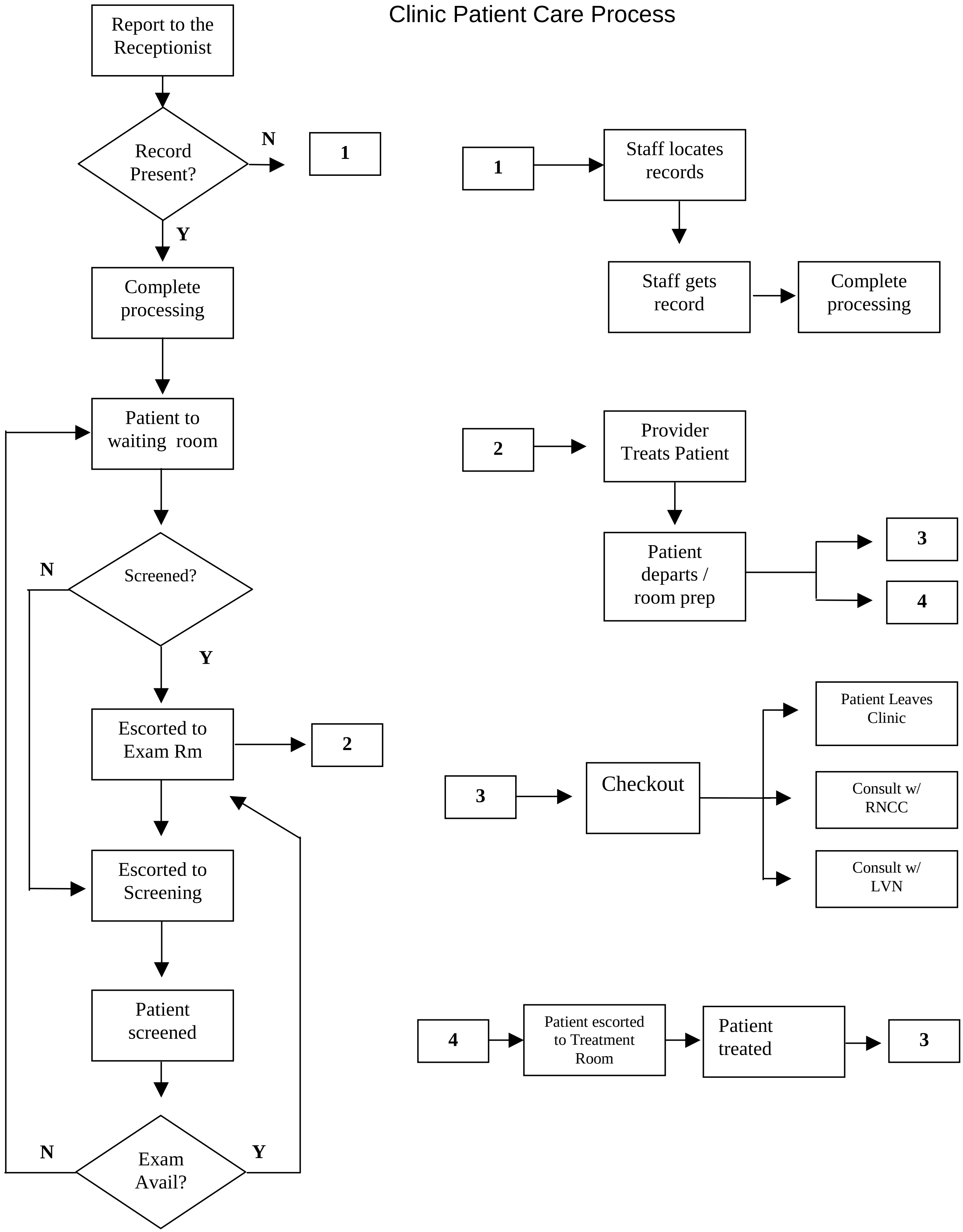
Steps in a Simulation Study



(Adapted from Bateman, Bowden, Gogg, Harrell, Mott, 1997)

Appendix B

Clinic Patient Care Process



Appendix C

Time and Motion Study Instrument

1. Date________________
2. Patients SSN ______-_____-________

3. Time of scheduled appointment_________ or WALK-IN(circle)
   If walk – in: UCC transfer / Blood Pressure / Unscheduled appt / Other ______________________.

4. APPT Type Acute / Follow Up / Routine / Wellness

5. Registration Start ______
   Registration End ______

6. Is the medical record present? Y / N

7. Time screening started ________
   Time screening ended ________

8. Time patient seen by the provider _______
   Time patient finishes with provider _______

Does this patient require any same day follow up care? (For example, did the patient go get x-rays?) Y / N
For what?____.

9. Treatment required in the treatment room? Y / N Initiate treatment log.
   If Y then what type of treatment____.

10. Need to see Nurse Care Coordinator? Y / N If Y go to 11, N go to 12.

11. Care Coordination Start ________
    Care Coordination End ________

12. Does this patient need to make a follow up appt.? Y / N If Y go to 13, if N end data collection.

13. Schedule follow up appt.

    Start time_______
    Complete time______

If this sheets gets separated from the ADS sheet, please deliver to one of the following:

GOPC: SSG Strode
TPC: CPT Hernandez or Ms. Ortiz

Appendix D

Reception Log

<u>Walk ins</u>

UCC

Blood Pressure Checks

Unscheduled Appts

Other

<u>Patient cancellations / No shows:</u>

Same Day Cancellation

Did not show up at all

Showed up late

Appendix E

Daily Workload 5 Feb 01 – 2 Mar 01

		5 Feb (Mon)			6 Feb (Tue)			7 Feb (Wed)			8 Feb(Thur)			9 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
Total Seen	86	136	222	103	114	217	117	89	206	59	105	164	53	95	148
		12 Feb (Mon)			13 Feb (Tue)			14 Feb (Wed)			15 Feb(Thur)			16 Feb (Fri) Holiday	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
Total Seen	109	124	233	76	112	188	100	107	207	101	142	243			
		19 Feb (Mon) Holiday			20 Feb (Tue)			21 Feb (Wed)			22 Feb(Thur)			23 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
Total Seen			0	107	93	200	107	90	197	61	83	144	85	139	224
		26 Feb (Mon)			27 Feb (Tue)			28 Feb (Wed)			1 Mar (Thur)			2 Mar (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
Total Seen	86	124	210	87	65	152	81	84	165	69	116	185	75	89	164

Appendix F

Arrival Frequency 5 Feb 01 – 2 Mar 01

		5 Feb (Mon)			6 Feb (Tue)			7 Feb (Wed)			8 Feb(Thur)			9 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	1	12	13	18	25	43	0	7	7	10	20	30	11	23	34
10:00 - 11:00	12	19	31	15	15	30	20	10	30	13	17	30	23	19	42
11:00 - 12:00	10	14	24	12	7	19	15	7	22	6	10	16	10	11	21
12:00 - 13:00	7	8	15	8	5	13	9	7	16	4	5	9	4	1	5
13:00 - 14:00	17	21	38	18	14	32	23	16	39	11	14	25	0	0	0
14:00 - 15:00	10	19	29	12	5	17	16	12	28	10	5	15	0	0	0
15:00 - 16:00	7	14	21	9	13	22	11	5	16	3	8	11	4	12	16
16:00 - 17:00	8	19	27	6	19	25	7	14	21	0	16	16	3	19	22

		12 Feb (Mon)			13 Feb (Tue)			14 Feb (Wed)			15 Feb(Thur)			16 Feb (Fri) Holiday	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	1	8	9	6	22	28	0	8	8	16	27	43			
10:00 - 11:00	16	17	33	11	15	26	14	19	33	17	18	35			
11:00 - 12:00	16	12	28	13	12	25	15	13	28	12	10	22			
12:00 - 13:00	9	8	17	8	7	15	7	9	16	6	9	15			
13:00 - 14:00	20	19	39	11	13	24	13	14	27	11	17	28			
14:00 - 15:00	14	16	30	8	4	12	12	13	25	13	15	28			
15:00 - 16:00	8	13	21	4	10	14	14	8	22	7	17	24			
16:00 - 17:00	9	20	29	6	18	24	7	11	18	5	16	21			

		19 Feb (Mon) Holiday			20 Feb (Tue)			21 Feb (Wed)			22 Feb(Thur)			23 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00			0	4	6	10	4	6	10	12	18	30	8	23	31
10:00 - 11:00			0	15	8	23	15	14	29	11	14	25	11	16	27
11:00 - 12:00			0	14	8	22	21	4	25	10	9	19	12	12	24
12:00 - 13:00			0	10	5	15	11	5	16	6	4	10	8	8	16
13:00 - 14:00			0	19	17	36	15	15	30	7	6	13	14	20	34
14:00 - 15:00			0	16	13	29	11	11	22	2	3	5	6	17	23
15:00 - 16:00			0	8	11	19	10	7	17	2	8	10	6	14	20
16:00 - 17:00			0	8	15	23	8	17	25	3	13	16	7	19	26

		26 Feb (Mon)			27 Feb (Tue)			28 Feb (Wed)			1 Mar (Thur)			2 Mar (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	3	9	12	20	12	32	2	8	10	7	18	25	17	26	43
10:00 - 11:00	17	19	36	15	11	26	14	15	29	9	14	23	22	17	39
11:00 - 12:00	13	8	21	12	6	18	18	9	27	11	8	19	13	12	25
12:00 - 13:00	6	6	12	9	3	12	8	4	12	6	7	13	4	2	6
13:00 - 14:00	13	19	32	18	12	30	13	14	27	12	18	30	5	0	5
14:00 - 15:00	10	16	26	2	6	8	5	9	14	8	13	21	6	0	6
15:00 - 16:00	6	12	18	0	0	0	4	6	10	3	15	18	4	9	13
16:00 - 17:00	7	19	26	6	12	18	9	10	19	3	14	17	8	16	24

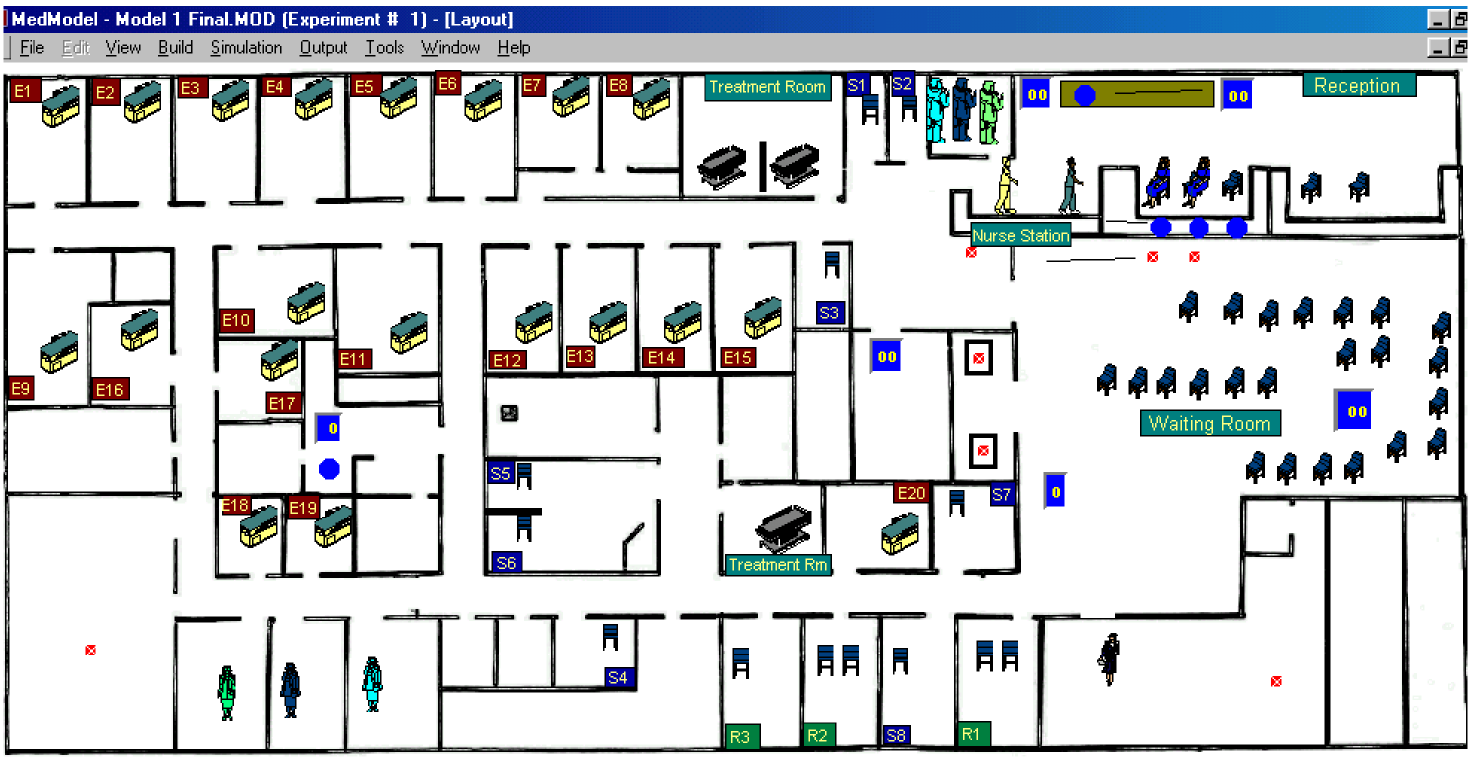
Appendix G

T-CONs Arrival Frequency 5 Feb 01 – 2 Mar 01

		5 Feb (Mon)			6 Feb (Tue)			7 Feb (Wed)			8 Feb (Thur)			9 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	1	5	6	1	2	3	1	0	1	1	2	3	2	2	4
10:00 - 11:00	1	9	10	1	1	2	0	3	3	0	0	0	0	2	2
11:00 - 12:00	1	1	2	0	2	2	0	1	1	0	0	0	0	1	1
12:00 - 13:00	0	0	0	0	1	1	0	0	0	2	1	3	3	0	3
13:00 - 14:00	0	1	1	1	3	4	1	4	5	0	1	1	0	1	1
14:00 - 15:00	0	0	0	3	1	4	1	1	2	0	2	2	0	1	1
15:00 - 16:00	1	2	3	2	1	3	1	1	2	1	1	2	0	3	3
16:00 - 17:00	0	3	3	0	0	0	1	3	4	1	1	2	0	0	0
		12 Feb (Mon)			13 Feb (Tue)			14 Feb (Wed)			15 Feb(Thur)			16 Feb (Fri) Holiday	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	0	1	1	0	4	4	0	1	1	1	1	2			
10:00 - 11:00	0	3	3	0	3	3	1	3	4	0	2	2			
11:00 - 12:00	0	3	3	1	2	3	0	4	4	0	0	0			
12:00 - 13:00	0	1	1	0	1	1	1	1	2	0	0	0			
13:00 - 14:00	0	1	1	1	5	6	1	4	5	0	1	1			
14:00 - 15:00	0	1	1	1	0	1	0	1	1	0	1	1			
15:00 - 16:00	0	0	0	0	1	1	0	1	1	0	0	0			
16:00 - 17:00	0	0	0	0	1	1	1	1	2	2	0	2			
		19 Feb (Mon) Holiday			20 Feb (Tue)			21 Feb (Wed)			22 Feb(Thur)			23 Feb (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00			0	0	3	3	0	3	3	2	1	3	1	4	5
10:00 - 11:00			0	5	2	7	0	2	2	0	0	0	0	1	1
11:00 - 12:00			0	0	0	0	0	0	0	0	1	1	1	1	2
12:00 - 13:00			0	1	1	2	0	3	3	0	1	1	0	0	0
13:00 - 14:00			0	0	1	1	0	3	3	0	2	2	0	3	3
14:00 - 15:00			0	0	0	0	0	1	1	0	1	1	0	0	0
15:00 - 16:00			0	0	0	0	0	2	2	1	6	7	0	0	0
16:00 - 17:00			0	0	2	2	0	0	0	0	3	3	0	1	1
		26 Feb (Mon)			27 Feb (Tue)			28 Feb (Wed)			1 Mar (Thur)			2 Mar (Fri)	
	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total	GOPC	TPC	Total
08:45 -10:00	1	0	1	0	1	1	3	1	4	0	3	3	5	4	9
10:00 - 11:00	1	1	2	0	0	0	2	0	2	2	3	5	1	1	2
11:00 - 12:00	4	1	5	0	1	1	5	1	6	0	1	1	1	1	2
12:00 - 13:00	1	1	2	0	1	1	2	0	2	0	0	0	1	0	1
13:00 - 14:00	2	1	3	0	2	2	1	1	2	0	0	0	0	0	0
14:00 - 15:00	0	1	1	0	0	0	0	0	0	0	3	3	0	0	0
15:00 - 16:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16:00 - 17:00	0	3	3	3	1	4	1	0	1	0	0	0	2	4	6

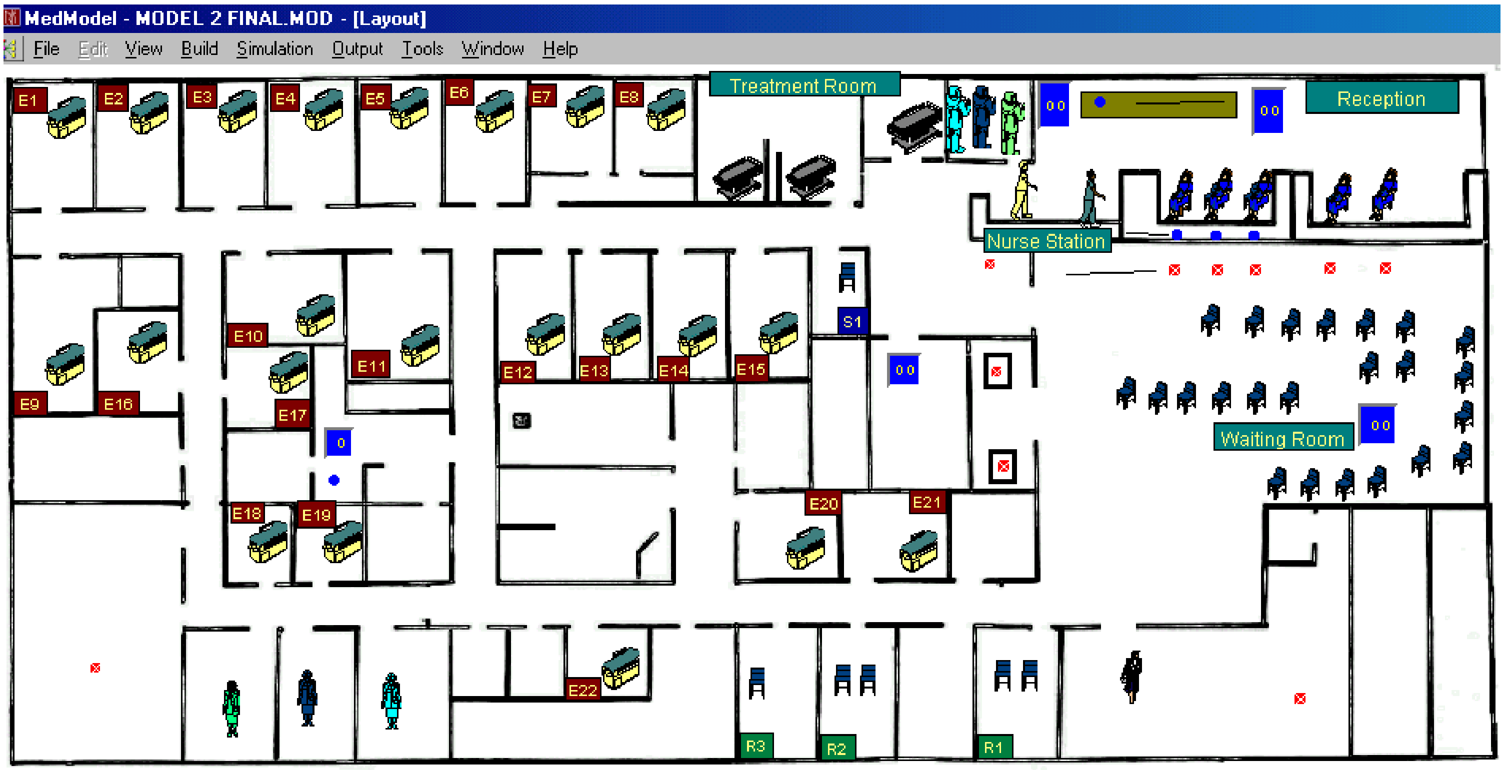
Appendix H

Current Floor Plan With Separate Screening Rooms (Model 1)



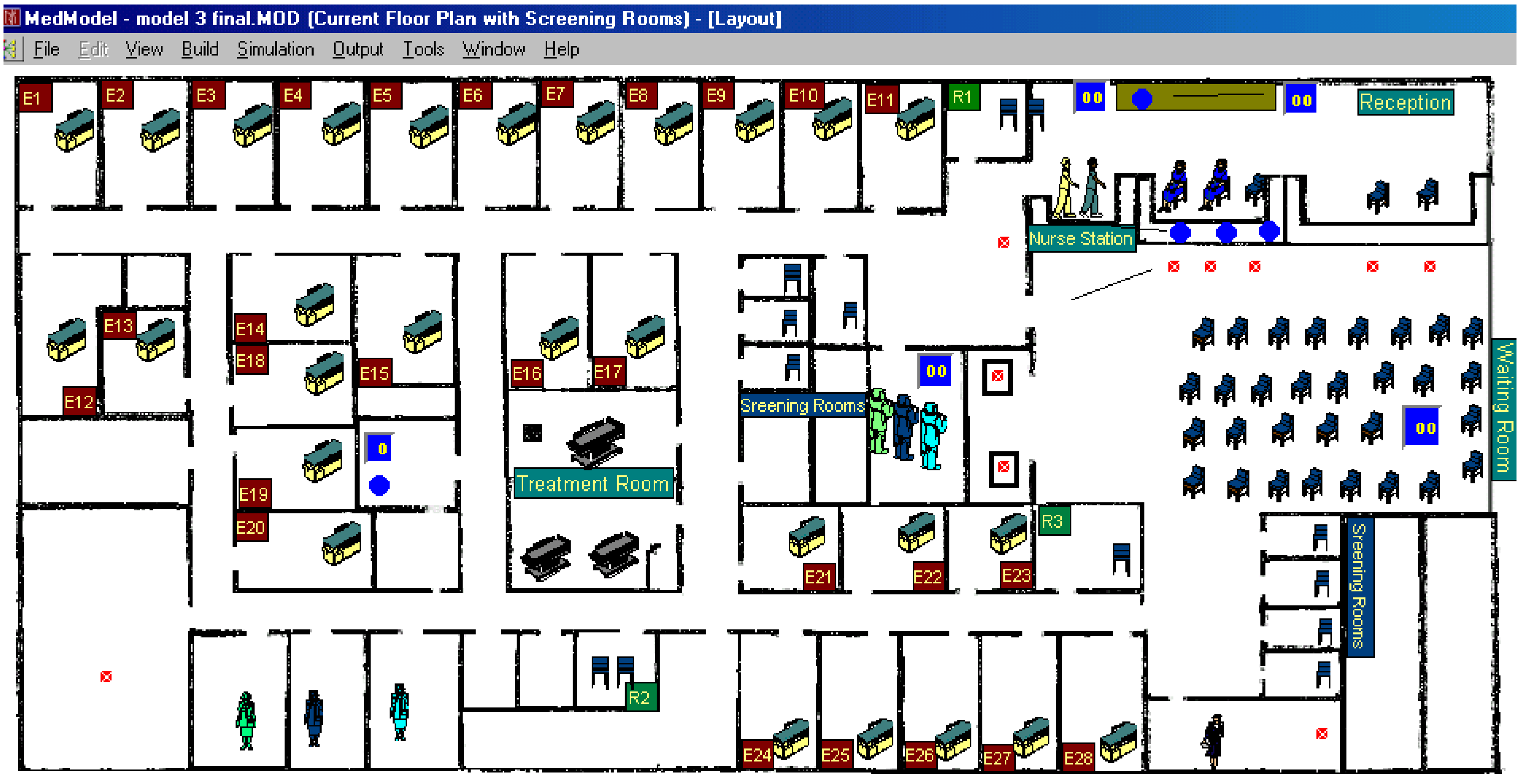
Appendix I

Current Floor Plan Without Separate Screening Rooms (Model 2)



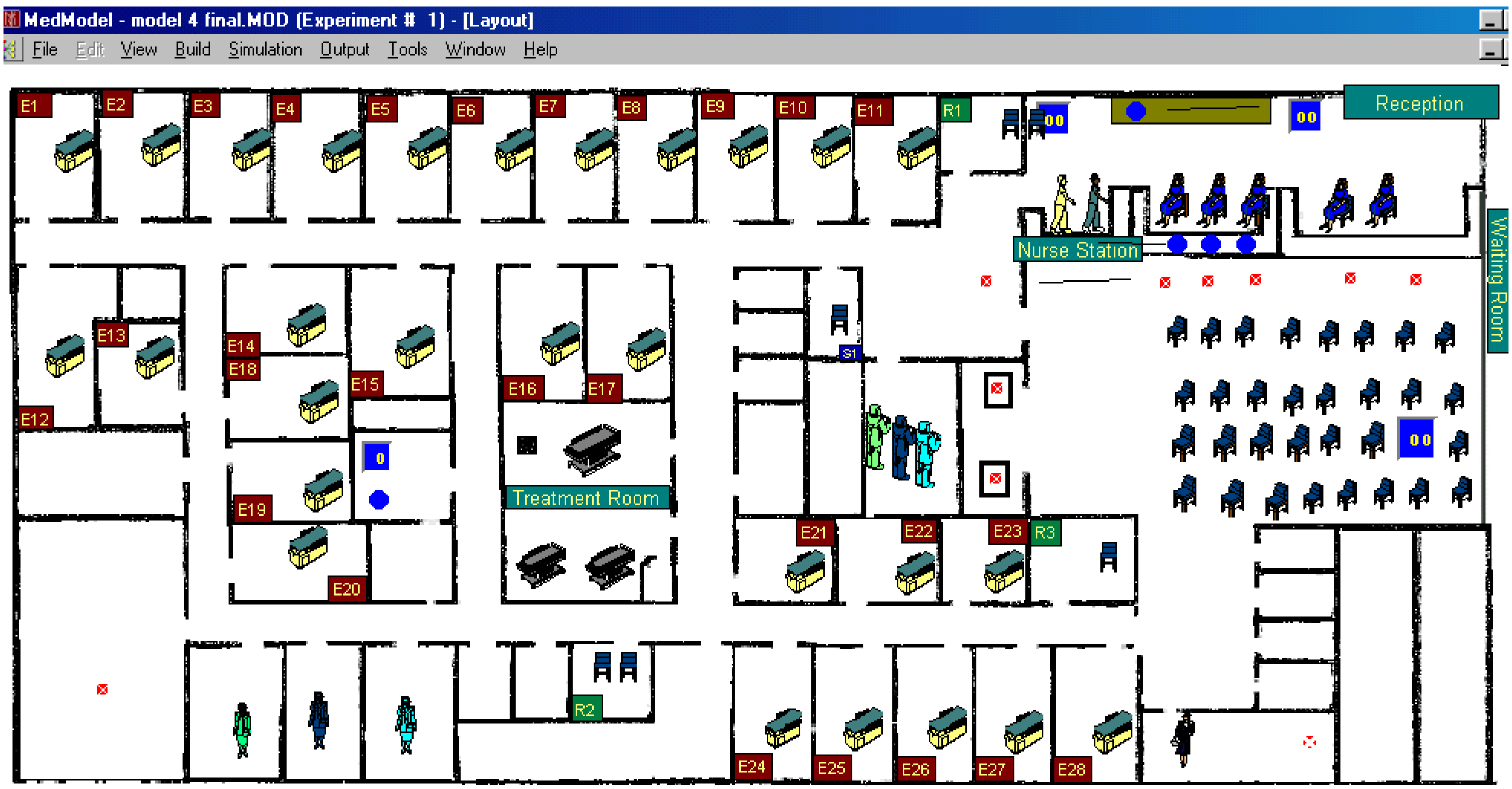
Appendix J

New Floor Plan With Separate Screening Rooms (Model 3)



Appendix K

New Floor Plan Without Separate Screening Rooms (Model 4)



Appendix L

Validity Test of Actual to Model Generated Average Daily Visits

Workload Comparison for Feb 01

Appts	Walk In	Sick Call	Tcon	Total
3818	441	1347	338	5944

Visits after 1700 hrs = 302
Workload between 0845-1730 = Total-(SC+TCONS+After 1700) = 3957 visits
Compared to Jan and Mar, visits in Feb were down approx 7%
3957 * 1.07 = 4234
Available days in Feb: 20
Daily Avg: 212
Average 6 month workload in the model: 28,400
Available days in the model: 130
Daily Avg: 218

Appendix M

SimmRunner Optimization Inputs

Model 1

Screening rooms available (4 to 8)
Team 1 exam rooms available (4 to 7)
Team 2 exam rooms available (4 to 7)
Team 3 exam rooms available (4 to 6)
Treatment rooms available (1 to 3)
Receptionist Available (2 to 5)
Provider Team 1 available (3 to 5)
Provider Team 2 available (3 to 5)
Provider Team 3 available (3 to 5)
Support staff team 1 available (2 to 5)
Support staff team 2 available (2 to 5)
Support staff team 3 available (2 to 5)
Treatment room staff available (2 to 5)

Model 2

Team 1 exam rooms available (4 to 8)
Team 2 exam rooms available (4 to 7)
Team 3 exam rooms available (4 to 7)
Treatment rooms available (1 to 3)
Receptionist Available (2 to 5)
Provider Team 1 available (3 to 5)
Provider Team 2 available (3 to 5)
Provider Team 3 available (3 to 5)
Support staff team 1 available (2 to 5)
Support staff team 2 available (2 to 5)
Support staff team 3 available (2 to 5)
Treatment room staff available (2 to 5)

Model 3

Screening rooms available (4 to 8)
Team 1 exam rooms available (4 to 10)
Team 2 exam rooms available (4 to 9)
Team 3 exam rooms available (4 to 9)
Treatment rooms available (1 to 3)
Receptionist Available (2 to 5)
Provider Team 1 available (3 to 5)
Provider Team 2 available (3 to 5)
Provider Team 3 available (3 to 5)
Support staff team 1 available (2 to 5)
Support staff team 2 available (2 to 5)
Support staff team 3 available (2 to 5)
Treatment room staff available (2 to 5)

Model 2

Team 1 exam rooms available (4 to 10)
Team 2 exam rooms available (4 to 9)
Team 3 exam rooms available (4 to 9)
Treatment rooms available (1 to 3)
Receptionist Available (2 to 5)
Provider Team 1 available (3 to 5)
Provider Team 2 available (3 to 5)
Provider Team 3 available (3 to 5)
Support staff team 1 available (2 to 5)
Support staff team 2 available (2 to 5)
Support staff team 3 available (2 to 5)
Treatment room staff available (2 to 5)

Appendix N

SimRunner Optimization Outputs

Model 1

Objective Function Terms that were measured:

Max: 5 * Screening room 1 (% Utilization)
Max: 5 * Screening room 2 (% Utilization)
Max: 5 * Screening room 3 (% Utilization)
Max: 5 * Screening room 4 (% Utilization)
Max: 5 * Screening room 5 (% Utilization)
Max: 5 * Screening room 6 (% Utilization)
Max: 5 * Screening room 7 (% Utilization)
Max: 5 * Screening room 8 (% Utilization)
Max: 5 * Exam room 1 (% Utilization)
Max: 5 * Exam room 2 (% Utilization)
Max: 5 * Exam room 3 (% Utilization)
Max: 5 * Exam room 4 (% Utilization)
Max: 5 * Exam room 5 (% Utilization)
Max: 5 * Exam room 6 (% Utilization)
Max: 5 * Exam room 7 (% Utilization)
Max: 5 * Exam room 8 (% Utilization)
Max: 5 * Exam room 9 (% Utilization)
Max: 5 * Exam room 10 (% Utilization)
Max: 5 * Exam room 11 (% Utilization)
Max: 5 * Exam room 12 (% Utilization)
Max: 5 * Exam room 13 (% Utilization)
Max: 5 * Exam room 14 (% Utilization)
Max: 5 * Exam room 15 (% Utilization)
Max: 5 * Exam room 16 (% Utilization)
Max: 5 * Exam room 17 (% Utilization)
Max: 5 * Exam room 18 (% Utilization)
Max: 5 * Exam room 19 (% Utilization)
Max: 5 * Exam room 20 (% Utilization)
Max: 5 * Treatment room 1 (% Utilization)
Max: 5 * Treatment room 2 (% Utilization)
Max: 5 * Treatment room 3 (% Utilization)

Max: 4.5 * Receptionist (% Utilization)
Max: 4.5 * Provider team 1 (% Utilization)
Max: 4.5 * Provider team 2 (% Utilization)
Max: 4.5 * Provider team 3 (% Utilization)
Max: 4.5 * Support staff team_1 (% Utilization)
Max: 4.5 * Support staff team_2 (% Utilization)
Max: 4.5 * Support staff team_3 (% Utilization)
Max: 4.5 * Treatment room staff (% Utilization)

Min: 4 * Time to complete exam (Average Value)

Min: 3 * Avg Time Wait for Resource (Average Value)

Min: 2.5 * Time to provider (Average Value)

Appendix O

Example of SimRunner Results

Solution 1

Screening rooms available = 4
Team 1 exam rooms available = 5
Team 2 exam rooms available = 6
Team 3 exam rooms available = 6
Treatment rooms available = 3
Receptionist Available = 2
Provider Team 1 available 3
Provider Team 2 available = 3
Provider Team 3 available = 3
Support staff team 1 available = 3
Support staff team 2 available = 3
Support staff team 3 available = 2
Treatment room staff available = 2
Objective Function: 6955.25

Solution 2

Screening rooms available = 7
Team 1 exam rooms available = 5
Team 2 exam rooms available = 6
Team 3 exam rooms available = 6
Treatment rooms available = 3
Receptionist Available = 2
Provider Team 1 available 3
Provider Team 2 available = 3
Provider Team 3 available = 3
Support staff team 1 available = 3
Support staff team 2 available = 2
Support staff team 3 available = 2
Treatment room staff available = 2
Objective Function: 6951.37

Solution 3

Screening rooms available = 5
Team 1 exam rooms available = 5
Team 2 exam rooms available = 6
Team 3 exam rooms available = 6
Treatment rooms available = 3
Receptionist Available = 2
Provider Team 1 available 3
Provider Team 2 available = 3
Provider Team 3 available = 3
Support staff team 1 available = 3
Support staff team 2 available = 3
Support staff team 3 available = 2
Treatment room staff available = 2
Objective Function: 6935.62

Solution 4

Screening rooms available = 4
Team 1 exam rooms available = 7
Team 2 exam rooms available = 6
Team 3 exam rooms available = 6
Treatment rooms available = 3
Receptionist Available = 2
Provider Team 1 available 3
Provider Team 2 available = 3
Provider Team 3 available = 3
Support staff team 1 available = 3
Support staff team 2 available = 3
Support staff team 3 available = 2
Treatment room staff available = 2
Objective Function: 6929.83

Appendix P

SimRunner Optimal Solutions

		Receptionist	Treatment area staffing	Support team 1	Support Team 2	Support Team 3	Provider Team 1	Provider Team 2	Provider team 3	Screening areas	Exam area 1	Exam area 2	Exam area 3	Treatment areas
	Top 25	2.6	2.0	3.1	2.4	2.2	3.0	3.0	3.0	5.4	5.7	5.4	6.0	3.0
	Top 10	2.4	2.0	3.1	4.5	2.1	3.0	3.0	3.0	4.7	5.8	5.5	6.0	3.0
	Top 3	2.3	2.0	3.0	2.3	2.0	3.0	3.0	3.0	5.3	5.0	5.7	6.0	3.0
	Top 1	2.0	2.0	3.0	2.0	2.0	3.0	3.0	3.0	4.0	5.0	6.0	6.0	3.0
Model 1	**Modeled**	**2**	**2**	**3**	**2**	**2**	**3**	**3**	**3**	**5**	**6**	**6**	**5**	**3**
	Top 25	4.2	3.3	4.0	3.2	2.3	3.0	4.1	3.0		6.0	5.8	6.9	1.2
	Top 10	4.4	3.2	4.0	3.0	2.2	3.0	4.0	3.0		6.0	6.0	6.9	1.3
	Top 3	4.7	3.0	4.0	3.0	2.3	3.0	4.0	3.0		6.3	6.0	7.0	1.3
	Top 1	5.0	3.0	4.0	3.0	2.0	3.0	4.0	3.0		7.0	6.0	7.0	1.0
Model 2	**Modeled**	**5**	**3**	**3**	**3**	**3**	**4**	**3**	**3**		**7**	**6**	**6**	**2**
	Top 25	2.4	2.1	3.4	2.1	3.0	3.0	3.0	3.0	6.0	9.1	6.2	8.4	1.2
	Top 10	2.2	2.2	3.6	2.0	3.0	3.0	3.0	3.0	6.2	8.8	6.3	8.5	1.3
	Top 3	2.0	2.0	3.3	2.0	3.0	3.0	3.0	3.0	6.0	9.0	6.0	8.7	1.3
	Top 1	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	6.0	10.0	7.0	9.0	1.0
Model 3	**Modeled**	**2**	**2**	**3**	**3**	**2**	**3**	**3**	**3**	**6**	**8**	**8**	**8**	**2**
	Top 25	4.7	2.0	3.3	3.8	3.2	3.0	3.0	3.0		9.9	7.2	8.1	2.0
	Top 10	4.8	2.0	3.0	3.4	3.6	3.0	3.0	3.0		10.0	7.3	8.2	2.0
	Top 3	4.7	2.0	3.3	3.7	4.0	3.0	3.0	3.0		9.0	7.7	8.3	2.0
	Top 1	5.0	2.0	3.0	3.0	4.0	3.0	3.0	3.0		9.0	9.0	8.0	2.0
Model 4	**Modeled**	**5**	**2**	**4**	**3**	**3**	**3**	**3**	**3**		**9**	**9**	**8**	**2**

Appendix Q

Example Model Replications Calculation

N = ((t(n-1), 1-α/2 S(n))/e)2

N = Number of Replication
S(n) = a point estimate of σ based on n model replications
t(n-1), 1-a/2 = critical value from the t-distribution
e = the amount of error between the estimated mean and the true mean

Replication	Avg time to complete exam	$(X_i - \bar{X})$	squared
1	39.87	-3.51	12.3482
2	46.86	3.48	12.08258
3	42.83	-0.55	0.306916
4	45.19	1.81	3.261636
5	42.59	-0.79	0.630436
6	43.63	0.25	0.060516
7	41.43	-1.95	3.818116
8	43.74	0.36	0.126736
9	42.54	-0.84	0.712336
10	45.16	1.78	3.154176
Total	433.84		36.50164
$\bar{X}$	43.38	S^2	4.056

Estimate of σ = S = SQRT of S2 = 2.013886

t(n-1), 1-a/2 = t_9 = 2.262

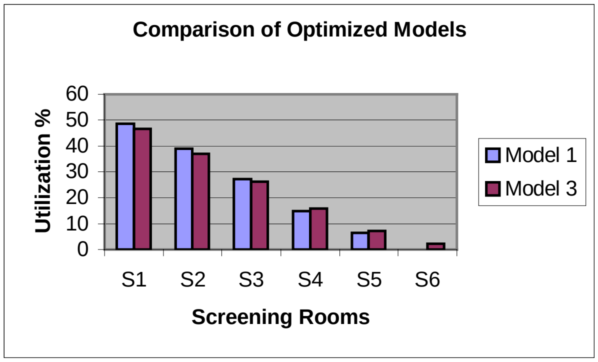
Formula Solved:

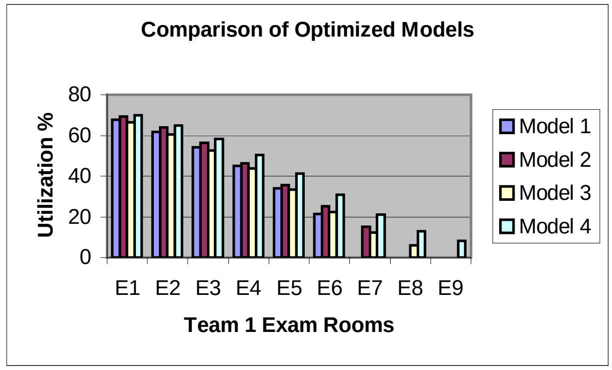
N = $\frac{(2.262)(1.827)}{2}$ = 2.278(sqrd) = 5.187942

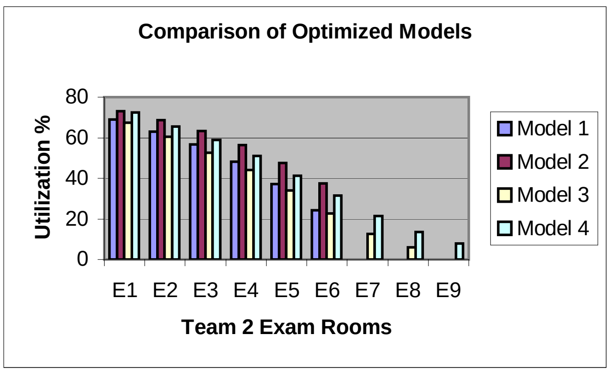
N = 5

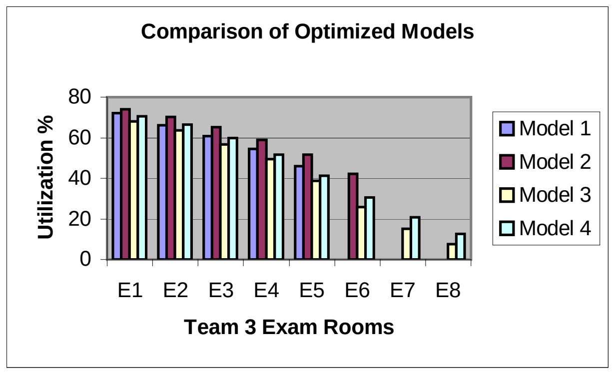
Appendix R

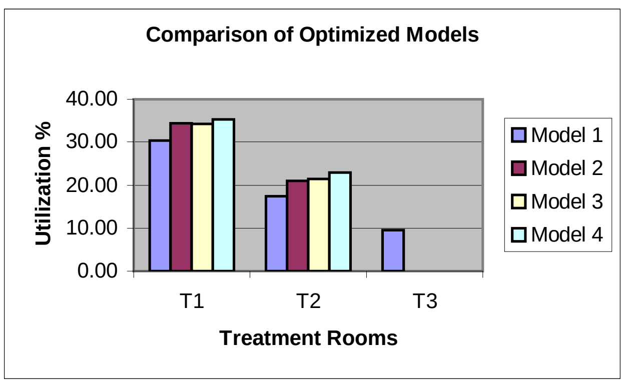
Location Comparison of Optimized Models





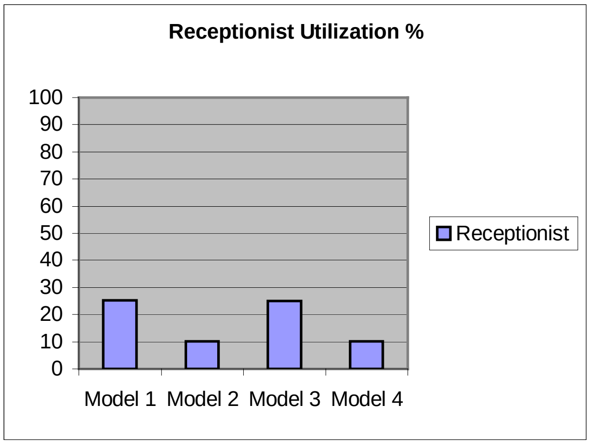


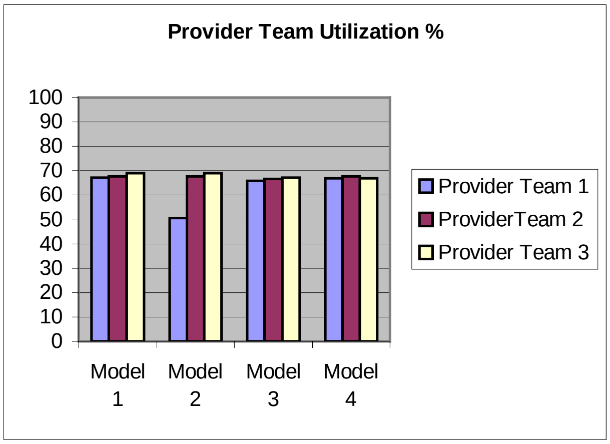


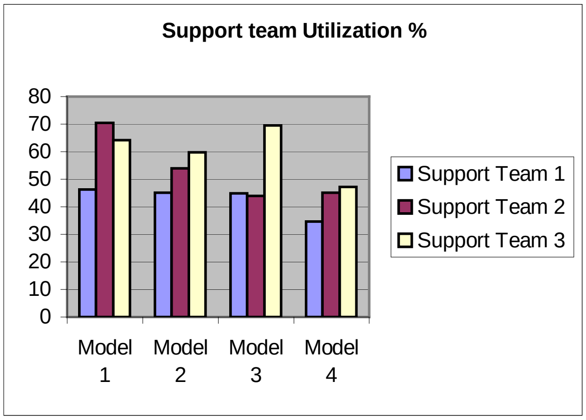


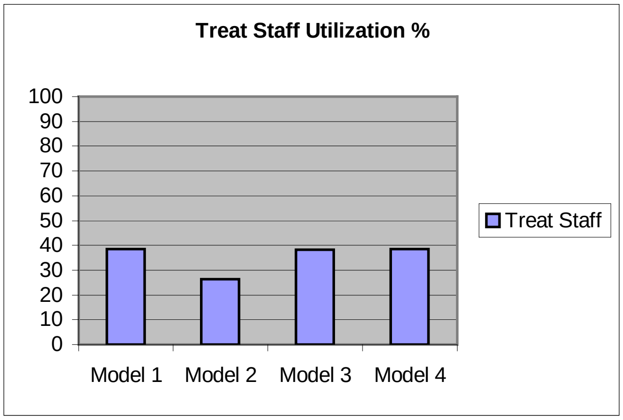
Appendix S

Resource Comparison of Optimized Models



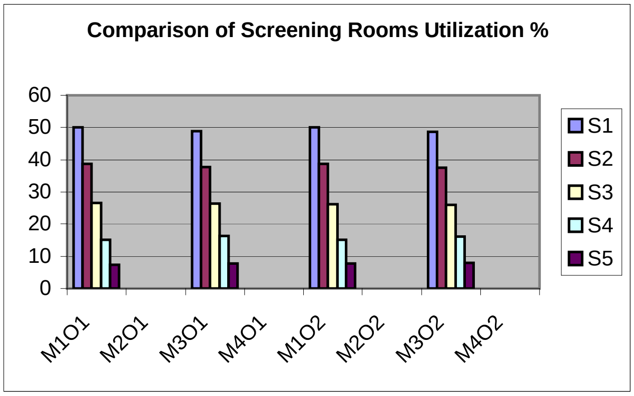


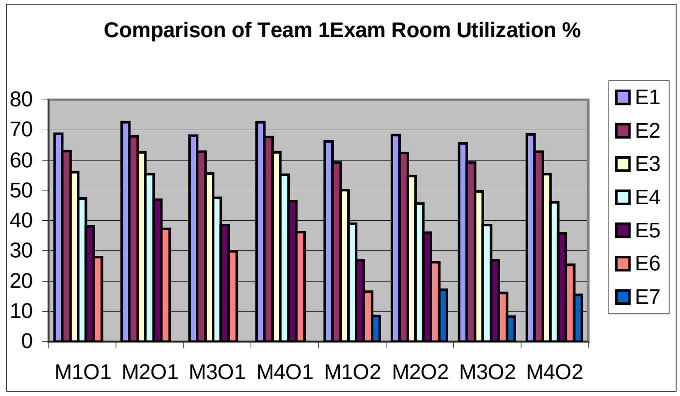


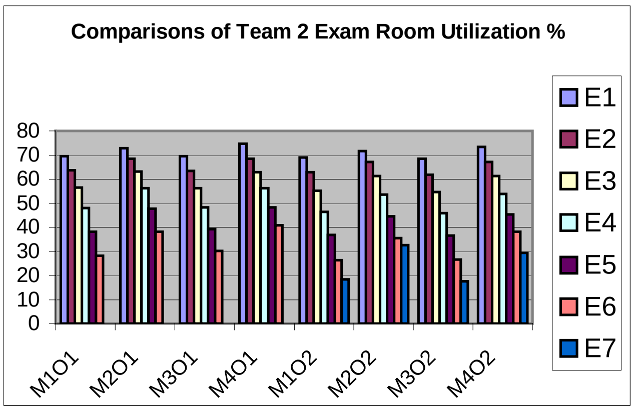


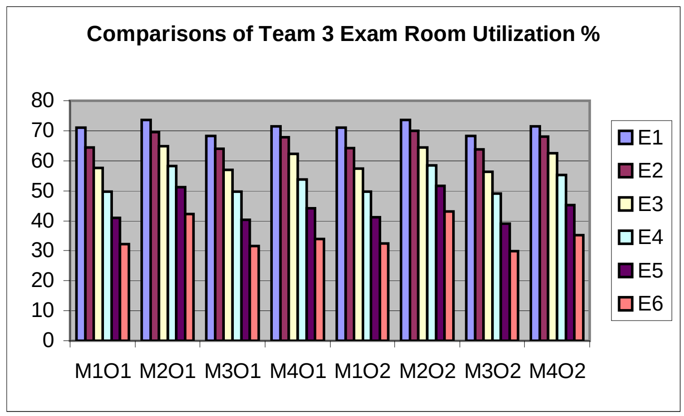
Appendix T

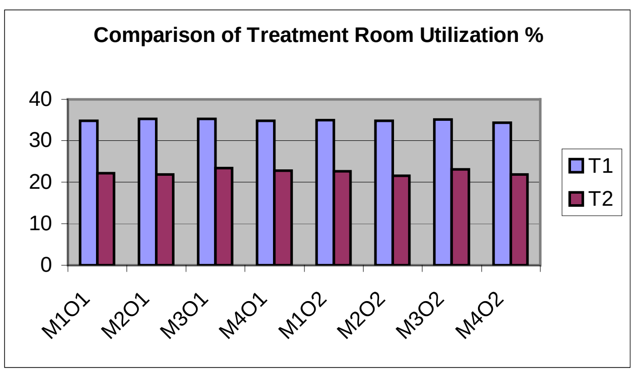
Location Comparison of Possible Solutions











Appendix U

Resource Comparison of Possible Solutions